

September 4, 2004

DECLARATION

The undersigned, Dana Scruggs, having an office at 8902B Otis Avenue, Suite 204B, Indianapolis, Indiana 46216, hereby states that she is well acquainted with both the English and German languages and that the attached is a true translation to the best of her knowledge and ability of PCT/DE 03/00926 (INV.: BLOCK, R., ET AL.), entitled "Method and Apparatus for Detecting the Motion of an Element".

The undersigned further declares that the above statement is true; and further, that this statement was made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or document or any patent resulting therefrom.



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Dana Scruggs

METHOD AND APPARATUS FOR DETECTING THE MOTION OF AN  
ELEMENT

Background Information

The present invention relates to a method and an apparatus for detecting the motion of an element relative to a sensor arrangement, in particular for detecting the angle of rotation of a rotating element, according to the definition of the species of the main claim.

Sensor arrangements of this type are already employed in different embodiments, in motor vehicles, for example. For example, with "Hall elements" as rotational speed sensors on the wheels for an antilock braking system (ABS), as rotational speed and phase sensors for engine management, or as steering-angle sensors for electronic stability systems, and for electronic power steering systems. These sensor arrangements, which are known from DE 197 50 304 A1, for example, typically emit digital signals, e.g., switching flanks, as a function of a trigger wheel rotating in front of the sensor.

Due to mechanical tolerances in particular, the most important requirements on these rotational speed sensors in an ABS and in engine and transmission systems include the greatest possible air gap and a high immunity to vibrations. A number of, at times, contradictory requirements are also placed on these sensor arrangements, whereby a highly sensitive sensor is also highly sensitive to excitation by the vibrations that interfere with the measured result. Full functionality should be achieved for very large air gaps, i.e., a highly sensitive sensor. At the same time, when air gaps are small, the aim should be to prevent the occurrence of faulty signals caused by vibrations when a sensor signal is high.

1 To minimize the sensitivity to vibrations of sensor arrangements of this type, a  
2 variable hysteresis is often used in conventional rotational speed sensors. In this  
3 case, the signal amplitudes must first be measured and the hysteresis is then  
4 adapted in a flexible manner. A large hysteresis is used for high input signals,  
5 and a correspondingly reduced hysteresis is selected for small input signals, i.e.,  
6 the amplitude required for switching is increased when the air gap is small.

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8 At the same time, the sensor is also required to be immune to vibrations,  
9 particularly when the trigger wheel is at a standstill; this works against high  
10 sensitivity and makes it necessary to realize a large switching hysteresis.

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12 A further aim is for the realized sensor to be insensitive to short-term signal  
13 changes, in particular to a marked amplitude reduction during operation. A main  
14 disadvantage of this method with a flexible hysteresis is therefore the loss of  
15 immunity against air gap impacts during operation in particular, which can  
16 generate a considerable, short-term reduction of the signal amplitude of this very  
17 type. As a result of a previously increased hysteresis at the switching point of the  
18 sensor, an air gap impact of this type may result in a loss of signal and/or a  
19 signal breakdown.

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21 Furthermore, the sensor need only be calibrated first for the method to be used  
22 with an adaptable hysteresis, since the signal amplitude is not known until after  
23 calibration. To correctly adjust the hysteresis, the sensor would first have to  
24 measure the signal amplitude, however. Since no measured values are available  
25 immediately after switching on, a starting value—typically the minimum—for the  
26 hysteresis must be selected in the sensor. At the same time, this also means that  
27 the sensor is very sensitive to vibrations in this state, however.

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29 Moreover, due to an increased hysteresis resulting from magnetic stimulation  
30 (i.e., during rotation of the trigger wheel), the sensor also loses its robustness to

1 air gap impacts, which can drastically reduce the signal amplitude over a few  
2 periods.

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4 For example, the use of an adaptive hysteresis that depends on the signal  
5 amplitude is known from US 5,451,891 A1. In this case, a coupling factor is  
6 determined as the quotient of the measured sensor amplitude and the frequency  
7 and, based on this coupling factor, the hysteresis is adjusted in proportion to the  
8 product of the coupling factor and the frequency. With this known method, it is  
9 possible only to compensate for the behavior of passive sensors which deliver a  
10 very small signal for low excitation frequencies and output a very high amplitude  
11 for high frequencies. The behavior of sensors that deliver a constant internal  
12 signal amplitude independent of the signal frequency cannot be improved,  
13 however.

#### 14 15 Advantages of the Invention

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17 The present invention relates to a further development of a method mentioned  
18 initially for detecting the motion of an element relative to a sensor arrangement,  
19 wherein switching signals are evaluated as a function of a pulse transmitter  
20 passing in front of the sensor, and a switching hysteresis is adapted in the  
21 evaluation as a function of the values of the switching signal.

22  
23 In advantageous fashion, according to the present invention, when the element  
24 moves below a predetermined limiting value, a relatively large switching  
25 hysteresis is set, and a reduced switching hysteresis is set when the limiting  
26 value is exceeded. The core of the invention therefore lies in the implementation  
27 of a frequency-dependent hysteresis that may be supplementable with an  
28 amplitude-dependent hysteresis. The predetermined limiting value is preferably a  
29 limiting frequency for the measured switching signals, which are evaluated as  
30 switching signals from a trigger wheel, as pulse transmitter, in particular during  
31 detection of the motion of a rotatable element, e.g., a rotational speed sensor.

1 It can therefore be achieved in a simple manner that a high immunity to vibration,  
2 i.e., no additional vibration pulses are produced, exists below the limiting  
3 frequency essentially in the standstill state, thereby ensuring great robustness to  
4 air gap impacts above this limiting frequency, i.e., no pulses are missing. In  
5 addition to the evaluation of the signal frequency relative to the limiting  
6 frequency, any type of standstill detection can be used to achieve the activation  
7 of the relatively large starting hysteresis.

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9 According to an advantageous embodiment, a previously measured amplitude of  
10 the switching signal can be used to determine the relatively large switching  
11 hysteresis, as starting hysteresis. According to another advantageous  
12 embodiment, a fixed value can be used for the relatively large switching  
13 hysteresis, as starting hysteresis, and/or the reduced switching hysteresis after  
14 the limiting value is exceeded and/or after the standstill has ended.

15  
16 Drawing

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18 An exemplary embodiment of the present invention for detecting the motion of an  
19 element relative to a sensor arrangement is explained with reference to the  
20 drawing.

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22 Figure 1 shows a diagram of the shape of the curve of a sensor signal  
23 from the sensor arrangement and a switching hysteresis over time,  
24 whereby the sensor signal is formed of switching signals during the  
25 standstill and the rotational motion of a trigger wheel,

26  
27 Figure 2 shows a diagram of the course of the switching hysteresis as a  
28 function of frequency during evaluation of the sensor signal,

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30 Figure 3 shows a diagram of the course of a switching hysteresis that is  
31 dependent on the amplitude of the sensor signal, and

Figure 4 shows a flow chart for determining the switching hysteresis.

#### Detailed Description of the Exemplary Embodiment

Figure 1 shows a diagram of course 1 of a sensor signal of the sensor arrangement over time  $t$ , which is determined here in the detection of the rotational motion of a trigger wheel known in principle from the related art, e.g., to generate pulses for predetermined angles of rotation. In the left part of the diagram according to Figure 1, a range 2 is defined as the standstill of the trigger wheel, which is not shown here. This range 2 can be defined as the range below a predetermined limiting value  $f_{\text{Grenz}}$ , as indicated in parallel in Figure 2.

Figure 2 shows course 3 of a switching hysteresis  $H$  as a function of frequency  $f$  in the evaluation of sensor signal 1 according to Figure 1. A relatively large switching hysteresis 4 is selected in region 2 as  $\text{Hyst0}$ , so that vibrations 5 do not result in a few signals that falsify the measured result.

After leaving standstill range 2 according to Figure 1 and/or after limiting value  $f_{\text{Grenz}}$  is exceeded according to Figure 2, a reduced switching hysteresis  $H1$  is set in range 6. Figure 2 therefore shows a fixed hysteresis  $H = \text{Hyst0}$  for a signal frequency  $f < f_{\text{Grenz}}$  and a fixed hysteresis  $H = H1$  for  $f > f_{\text{Grenz}}$ .

Figure 3 shows a combination of fixed hysteresis  $H$  according to Figure 2 with an amplitude-dependent hysteresis  $H$ . A course 7 of hysteresis  $H$  plotted against signal amplitude  $SA$  is shown. Fixed hysteresis  $H = \text{Hyst0}$  is adapted here based on a previously measured signal amplitude  $SA$ , i.e., fixed hysteresis  $\text{Hyst0}$  is a function of amplitude. If it was not possible to measure signal amplitude  $SA$  in advance, e.g., directly after the sensor arrangement was switched on, this can take place via the selection of a preset value (a default value).

1 Figure 4 shows a flow chart depicting the mode of operation of a sensor  
2 according to the present invention, including the determination of switching  
3 hysteresis H explained with reference to Figures 1 through 3. Starting with the  
4 detection of a standstill STST, e.g.,  $f < f_{\text{Grenz}}$ , the large switching hysteresis Hyst0  
5 is first set. Then, motion of the trigger wheel is detected via the measured signal  
6 amplitude SA (refer to position 1 in Figure 1), and switching hysteresis H is then  
7 reduced to value H1. A new value for Hyst0 can be determined from signal  
8 amplitude SA which is then measured, and said new value is used when  
9 standstill occurs again.

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